THE PROPAGATION OF EXPLOSIONS IN MIXTURES OF PETROLEUM VAPOR WITH AIR IN TUBES.

By CHARLES E. MUNROE,

Professor of Chemistry, George Washington University, Washington, D. C.

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On May 12, 1902, a series of accidents from fire and explosions occurred at or contiguous to the Sheraden Yard of the P. R. R. at Pittsburg, Pa., as the result of the collision of a tank car containing "stove naphtha" with another car, or cars, whereby the tank car was perforated and naphtha escaped. As the collision occurred in the late afternoon at a time when the yard switch lamps and the lamps of other safety devices had been lighted, the vapors of the naphtha which was spilled from the perforated tank car, became ignited and through the conflagration thus initiated other tank cars containing naphtha were heated to such a point as to force their contents out where they could contribute to the general conflagration, or, where, as in one instance certainly, the tank valve was too firmly set to thus yield to this effect, the tank itself was ruptured and its heated contents were discharged into the atmosphere, producing most disastrous results.

The Sheraden Yard was artificially constructed by filling a ravine between steep hills extending from the high ridge along the of level surface required for so extensive a railroad yard. As Ohio River, near the confluence of the Alleghany and Monongohela rivers, to the northwest of Pittsburg, so as to obtain the area might have been expected, the bottom of the ravine was occupied by a stream, known as Cork Run, and this was fed by several lateral streams which entered the ravine through fissures or ravines in the surrounding hills. Good engineering demanded the preservation of these water courses after the filling of the ravine, and this was done by means of sewers, the main one occupying, in general,

the bed of Cork Run, and its laterals those of the tributaries to Cork Run. The total length of the sewerage system thus constructed to the point where the collision occurred was 2,785 feet and the different sections varied in diameter from 2 feet at the head to 10 feet at the mouth where the sewer opened into the unfilled portion of the ravine near the Ohio River.

Immediately beside and parallel with the Ohio River was the road bed of the P. & L. E. R. R., a culvert having been built over Cork Run. Immediately beside this railroad embankment, but between it and the bluff was a turnpike road including its wooden bridge across Cork Run, this bridge being 19 feet above the bed of the run. Cork Run from the mouth of the sewer to the point of its discharge into the Ohio River, a distance of about 116 feet, was practically an open drain. The building of the tunpike across the ravine made a large pocket or basin at this point.

Naturally use was made of Cork Run sewer in draining Sheraden Yard, and, as a part of this system, catch basins for surface water from the yard were built and connected to the sewer, one of these catch basins being near the point at which the collision occurred.

Among other explosions, one occurred in the basin between the mouth of the sewer and the turnpike which was sufficiently violent to wreck many buildings in the vicinity and to lift from its track a trolley car, which was just approaching the turnpike bridge, with sufficient force to injure some of the passengers.

Among other theories, it was alleged that this explosion was due to naphtha which ran into the sewer through the catch basin above referred to, where its vapors formed, with air, a combustible mixture; that the vapors in the sewer were ignited by the fire burning in the yard about the mouth of the catch basin; and that the flame was transmitted through the sewer and caused the explosion of the accumulated air-vapor mixture in the basin.

In considering the probability of this theory being the correct one, the dimensions of the sewer throughout its complete length was ascertained and, from the volumes calculated from this data, it was found that 3,451 gallons of naphtha would furnish sufficient vapor to completely fill the sewer, while 200 gallons of the naphtha

would fill the sewer with a slightly combustible but non-explosive mixture. As the tank car, which was perforated beside the catch basin, contained 7,253 gallons of naphtha, there was a sufficient volume to more than satisfy the requirements for filling the sewer with naphtha vapors as set forth above.

That explosions occurred in or about portions of the sewer and its laterals seemed undoubted, yet recalling the safety lamp, the difficulty experienced in transmitting flames through tubes, and the varying capacities of columns of explosives of different diameters in propagating detonation, a doubt arose in my mind as to the flame traversing this sewer. Not finding any information on this matter in literature, experiments were made as follows:

RESULTS OF EXPERIMENTS.

No.	Date, 1903.	Kind of Tube.	Diameter, Inches.	Length, Inches.	Ratio of D : L.	Result.
1	Apr. 23	Glass	1.5	38	1 : 25.33	Positive
2	23	"	1.5	32	1 : 25.33	"
3	24	"	1	49	1 : 49	"
4	24	Steel	4	240	1 : 60	"
5	22	Glass	0.4	25⅜	1 : 63.44	Negative
6	22	"	0.4	25⅜	1 : 63.44	"
7	22	"	0.4	25⅜	1 : 63.44	"
8	23	"	0.4	25⅜	1 : 63.44	"
9	23	"	0.4	25⅜	1 : 63.44	"
10	23	"	0.4	25⅜	1 : 63.44	"
11	23	"	0.4	25⅜	1 : 63.44	"
12	24	"	1	78	1 : 78	"
13	24	"	1	78	1 : 78	"
14	24	"	1	78	1 : 78	"
15	24	Steel	4	480	1 : 120	"
16	24	"	4	480	1 : 120	"
17	24	"	4	480	1 : 120	"

It having been observed that if vessels were filled with the combustible mixture of naphtha vapor and air and the mixture was ignited at the mouth of the vessel, the flame retreated to various depths depending on the relation of the diameter of the vessel to its length, experiments were made with tubes. In conducting the experiments in each case the tube or pipe, which was open at both ends, was inclined at an angle and a considerable quantity of liquid naphtha was poured slowly into it at the upper end. So soon as the last of the liquid had been poured into the tube a flame was

applied to the upper end of the tube (called the mouth) to ignite the vapors and it was then noted if the flame traveled completely through the tube and issued from the bottom end or if it traveled but part way through and became extinguished. In every experiment there was some liquid naphtha as well as naphtha vapors throughout the tube at the moment when the flame was applied. Experiments were made in glass and steel tubes varying in diameter from .4 inch to 4 inches. The results are presented in the following table. When the flame traveled completely through the tube and issued from the bottom end the result is marked "positive." When the flame traveled but part way down the tube and became extinguished the result is marked "negative."

It appears then that where the length of the tube is 63.44 times its diameter or above this the flame does not travel through.